Overview of Clean Diesel Requirements and Retrofit Technology Options

Francisco J. Acevedo

Tools for Cleaning up Illinois Diesel: Technology, Funding, and Collaboration

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Naperville, Illinois

Regulatory Strategy

New Standards for NEW diesels

Diesel engines in all mobile source applications--

- ***Regulations adopted; now focused on implementation:***

Light-duty vehicles

- **Tier 2 Standards (1999 rulemaking)** – 77-95% lower light-duty vehicle standards (beginning in 2004)– Same standards for light trucks and cars; gasoline and diesel

Heavy-duty trucks & buses

- **Heavy-Duty 2007 Standards (2000 rulemaking)** – Diesel sulfur control (15 ppm maximum, beginning in 2006)– 90% lower heavy-duty gasoline & diesel vehicle standards

Nonroad machines

- **Nonroad Tier 4 Standards (2004 rulemaking)** – Diesel sulfur control (2 steps -500 ppm in 2007, 15 ppm in 2010)– 90-95% lower emission standards -based on highway technology

Regulatory Strategy

New Standards for NEW diesels

Diesel engines in all mobile source applications--

- ***Rulemakings underway for:***

Locomotives

Marine vessels

- **Locomotive and Marine Diesel Standards (in process-2006)** – Marine diesel sulfur control (15 ppm maximum) in 2012– Considering requiring same technologies

- **Diesel Retrofit (ongoing)** – Ultra-low sulfur diesel fuel enables advanced technologies– Realize substantial air quality and health benefits earlier

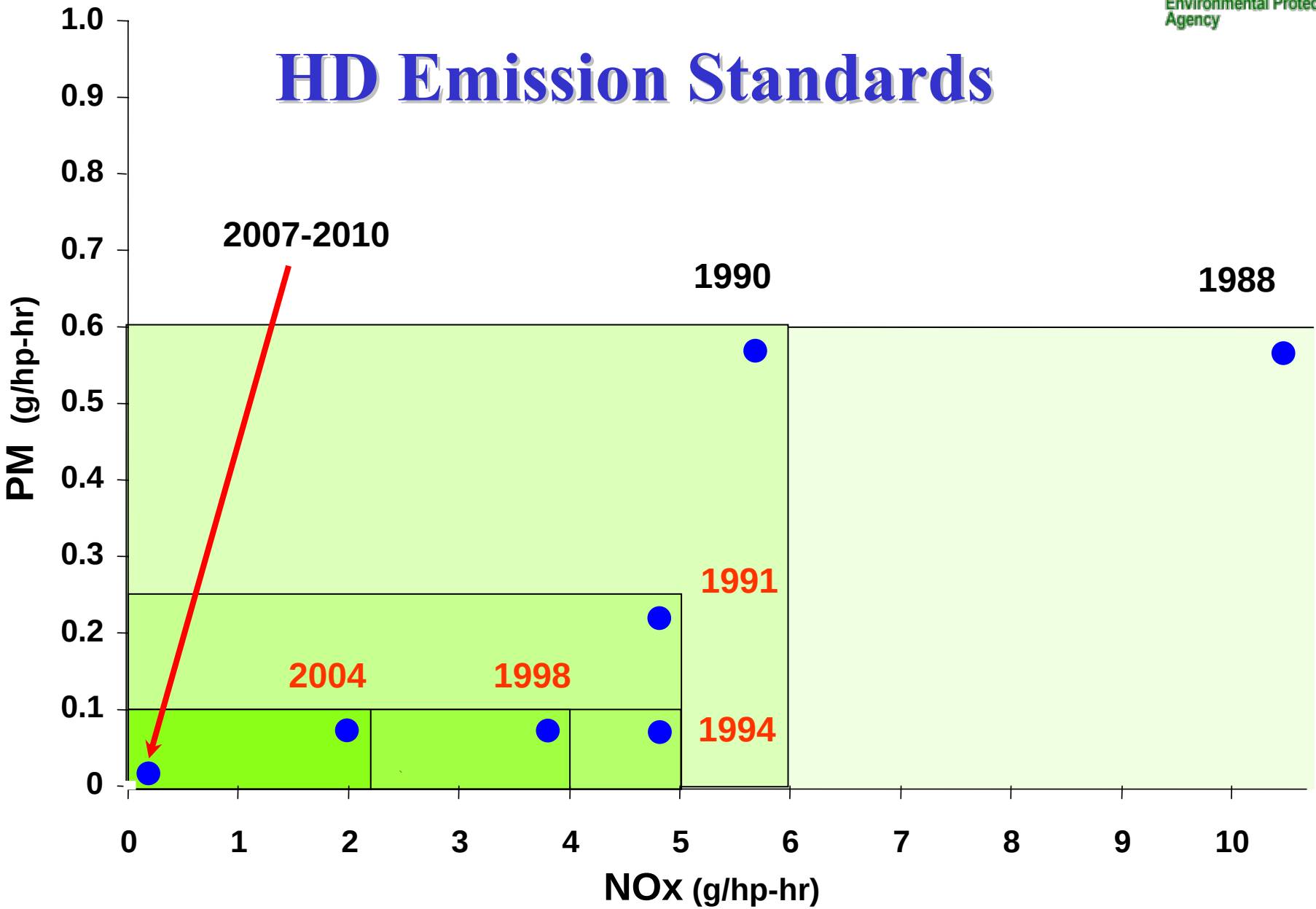
A New Approach to Clean Air Programs for Mobile Sources

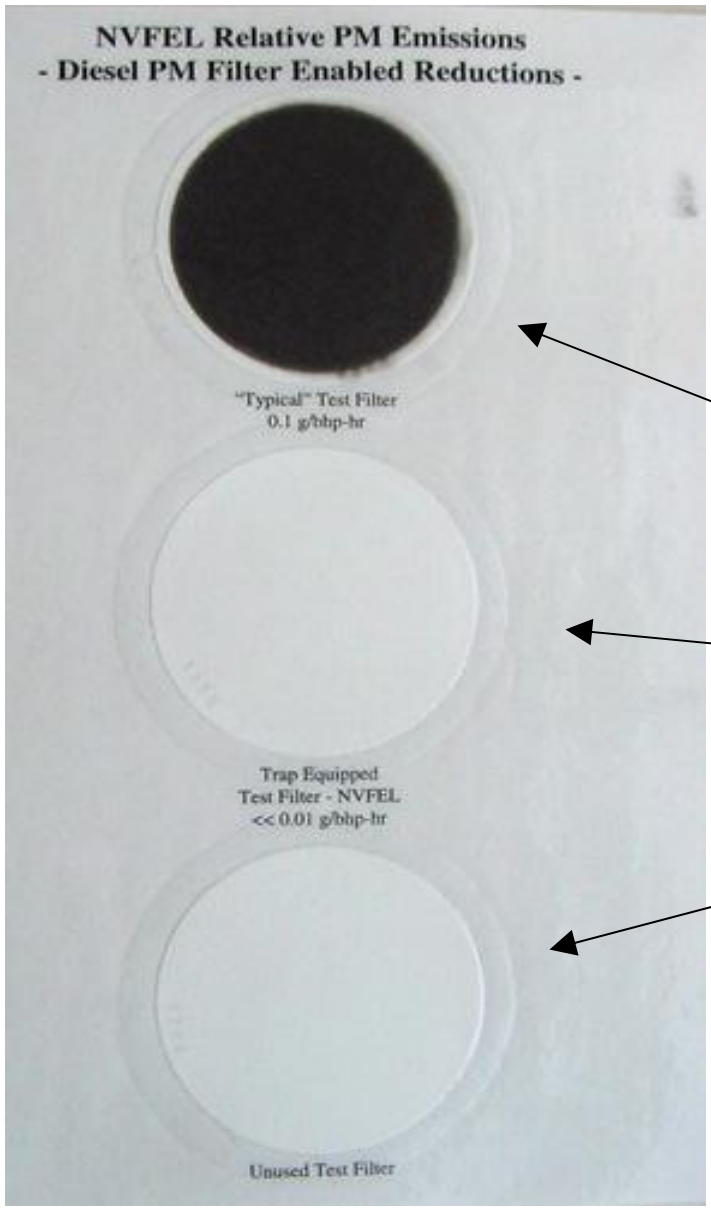
- In the past, EPA created separate programs for vehicle emission standards and cleaner fuels
- The new 2007 diesel program and the nonroad diesel program take a systems approach (vehicle & fuel) to optimize costs and benefits
- Also considers the inter-relationship with other programs (like gasoline desulfurization)

Heavy-Duty 2007 Standard Requirements

	2006	2007	2008	2009	2010	2011	2012
PM		**100%** at **0.01** g/hp-hr					
NOx		**50%** at **0.20** g/hp-hr			**100%** at **0.20** g/hp-hr		
Fuel		**80%** at **15 ppm maximum sulfur** (under temporary compliance option)				**100%** at **15 ppm**	

HD Emission Standards





PM Emissions with Trap

- Typical test filter – current standards
- Test filter – 2007 standards
- Unused test filter

Nonroad Program Requirements

EPA United States Environmental Protection Agency

- **Exhaust emission standards apply to diesel engines used in most kinds of construction, agricultural, and industrial equipment**
  - **–Excludes diesel engines used in locomotives or marine vessels**

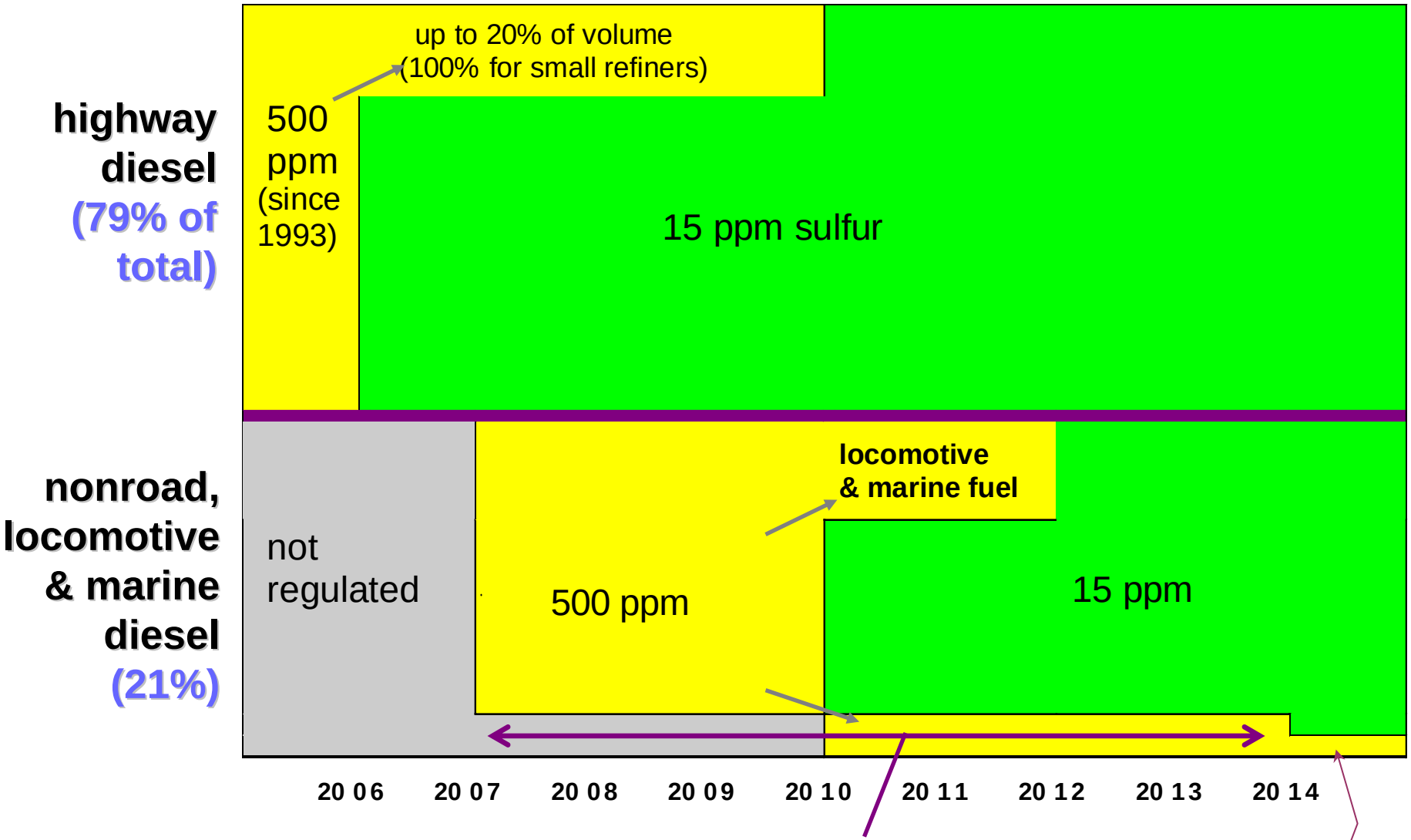
Rated Power	First Year that Standards Apply	PM (g/hp-hr)	NOx (g/hp-hr)
hp < 25	2008	0.30	-
25 ≥ hp < 75	2013	0.02	3.5*
75 ≥ hp < 175	2012-2014	0.02	0.30
175 ≥ hp < 750	2011 - 2013	0.01	0.30
hp > 750	2011 - 2014	0.01	0.30

Nonroad Diesel Rule Fuel Provisions

- 500 ppm cap on sulfur in 2007
  - for all nonroad diesel fuel including locomotive and marine applications
- 15 ppm cap on sulfur in 2010
- 99% reduction from current levels (~3,400 ppm)

Sulfur in Diesel Fuel

Regulations apply June 1 at refinery, Aug 1 at terminal, Oct 15 at retailer



for transmix, small refiner fuel, and thru use of credits, except in Northeast & Alaska
(expiration date not yet set for 500 ppm locomotive & marine transmix)

National Clean Diesel Campaign

- **Regulations for new engines**
  - Heavy-Duty Highway, Nonroad, Light-duty Tier 2
  - Upcoming standards for Marine/Locomotives
- **Voluntary Programs to address existing diesel fleet**
  - Voluntary Diesel Retrofit Program – Midwest Clean Diesel Initiative
    - Projects involving: diesel exhaust catalysts, particulate filters, engine modifications, cleaner fuels, idle reduction
    - Project evaluation, Communications & Outreach
  - SmartWay Transport
    - Projects involving: idle reduction, tires, logistics, lubricants, aerodynamics, speed management, ECM reflash
    - Communications & Outreach

Goal: By 2014 reduce emissions from the over 11 million engines in the existing fleet

The 5 Rs + Operational Strategies

- Refuel- Use of advanced diesel fuels, i.e. ULSD can lower emissions

- Retrofit- Installation of exhaust aftertreatment devices such as Diesel Oxidation Catalyst (DOC), Diesel particulate filters (DPF), etc

- Repair/Rebuild- regular engine maintenance plays a critical role in maintaining emissions performance while engine rebuilding can upgrade emissions performance of older engines.

- Repower – replacing older engines with newer cleaner engines

- Replace- replacing the entire equipment to ensure that your new purchase utilizes the most cost effective emission reduction technology

- Operational Strategies- utilizing various strategies to reduce idling

Refuel

- Low sulfur fuels: Ultra low sulfur diesel (ULSD): 15ppm
- EPA highway diesel (a.k.a., low sulfur diesel or LSD): 500ppm
- CARB highway diesel: 150ppm
- Emulsified Diesel - NOx (9-20%), PM (16-58%)
- Biodiesel
- Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG)
  - inherently cleaner
- Liquefied Petroleum Gas (LPG or propane)
  - Can reduce N0x and CO

Fuels -- ULSD

- Enabler for the application of advanced PM and NOx aftertreatment technologies
- Modest PM Reductions (5 to 7%)
- Easy to use “fill & go” technology; No engine modifications needed; Utilize existing fueling infrastructure;
- Path for mandated ULSD in 2006 (nonroad in 2010)
- No performance issues or fuel economy penalties;
- Incremental cost differential;
- Reduced lubricity overcome with additives
- Potential contamination issues with higher sulfur fuels at refinery and distribution points until federally mandated ULSD program takes effect.

Fuels – Emulsified Diesel

- Improved atomization of fuel mixture during injection
- Increased ignition delay; increased pre-mixed combustion
- Water slightly delays combustion => less PM (16-60%)
- Water cools combustion process => less NOx (9-20%)

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

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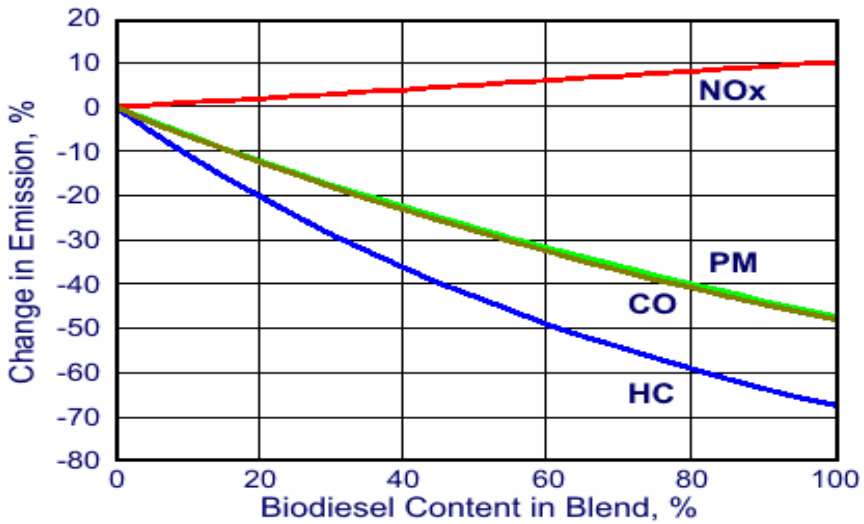
Fuels -- Biodiesel

- No sulfur or ultra low sulfur content
- No aromatics contents (and no PAHs)
- About 11% oxygen content (petrodiesel contains no oxygen)
- Higher cetane value (typically 45-60)
- Lower heating value
- Better lubricity
- Higher viscosity
- Higher freezing temperature

COST = 10 – 50 cents/gal.



Retrofit

- Existing emission controls systems can greatly reduce diesel particulate matter (PM) emissions
  - Diesel oxidation catalysts and diesel particulate filters
- Existing and developing emission control systems can greatly reduce NOx and PM emissions
  - Lean NOx catalysts, EGR, SCR and combined systems
- Technologies to control crankcase emissions

Retrofit Technology Verification

- Objective: Evaluate the emission reduction effectiveness of retrofit technology

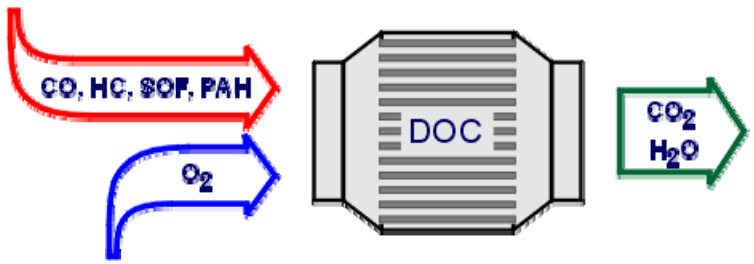
  - Verification provides stakeholders with confidence that these technologies will achieve quantifiable emission reductions

- Verification consists of the following:
  - Appropriate Testing Protocols
  - Statistical Sampling Methods
  - Durability Requirements

EPA
United States
Environmental Protection
Agency

Diesel Oxidation Catalyst (DOC)

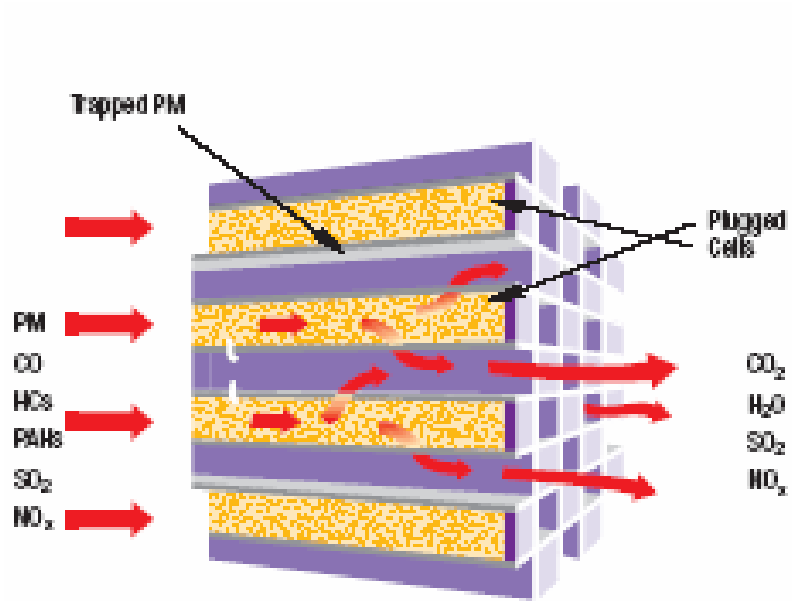
- What is it?
  - Device that oxidize pollutants in the exhaust stream and can be packaged with mufflers
- What does it do?
  - Reduces PM (10-50%), HC 50%, CO 40%
- Cost: $500 - $2,000
- Issues:
  - Most widely used technology
  - No maintenance required
  - Lower PM reductions than DPF
  - Applicable to most engines and vehicles
  - Verified for dockside and construction equipment



Hydrocarbons + O2 = CO2 + H2O
CO + ½ O2 = CO2

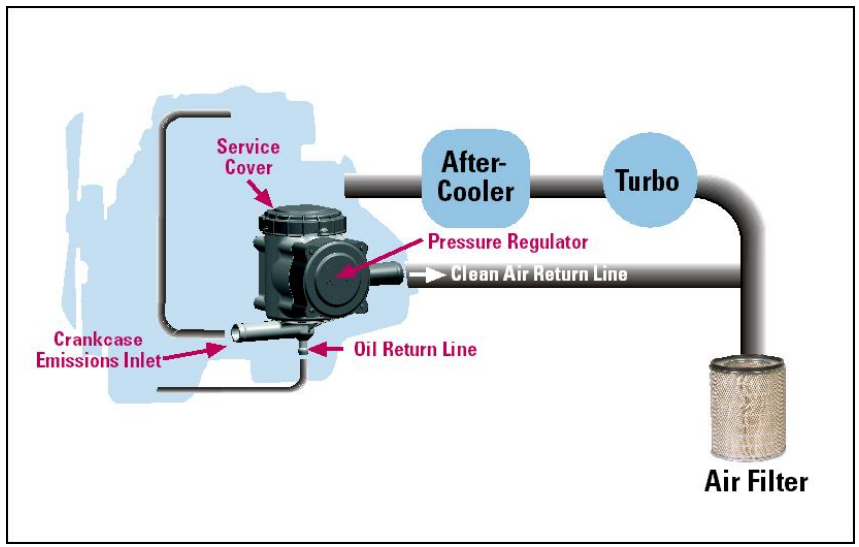
Diesel Particulate Filter (DPF)

- What is it?
  - Honeycomb or mesh devices placed within exhaust stream that physically trap and oxidize PM
- What does it do?
  - Reduces PM, HC, CO (+85%)
- Cost: $5,000 - $10,000
- Issues:
  - Must be used with ULSD
  - Passive filters require higher operating temp. (>250 C)
  - Periodic removal of unregenerated ash



Closed Crankcase Ventilation

- What is it?
  - System that directs crankcase "blow-by" emissions to intake system for re-combustion. PM collected in filter.
- What does it do?
  - Reduces PM (10%), HC, CO
- Cost: $700+
- Issues:
  - Likely used to meet 2007 requirements
  - Can be paired w/ DOC for greater reductions
  - Improved vehicle/equipment reliability
  - Keeps engine compartment and components clean
  - Reduces oil usage and operating costs



Selective Catalyst Reduction (SCR)

- What is it?
  - System injects urea (or some form of ammonia) into the exhaust stream and react over a catalyst to reduce NOx emissions.
- What does it do?
  - Reduces PM (~25%), NOx (60-90%)
- Cost: $10,500 - $50,000
- Issues:
  - Can be paired w/ DOC or DPF for greater reductions
  - Requires on-board urea injection system
  - CARB verified for certain dockside and construction equipment
  - Used in some marine vesels and locomotives

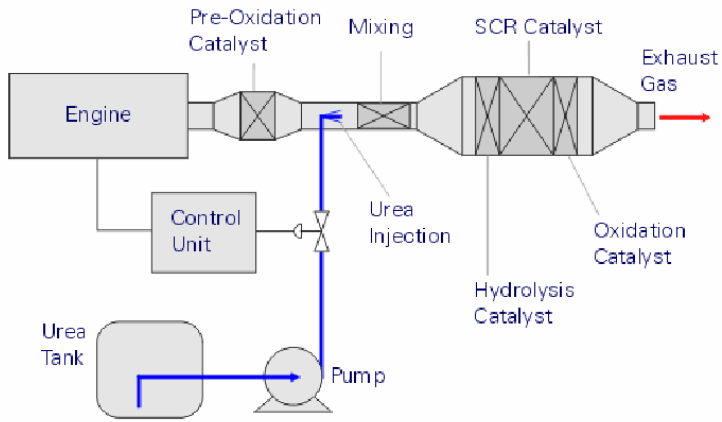
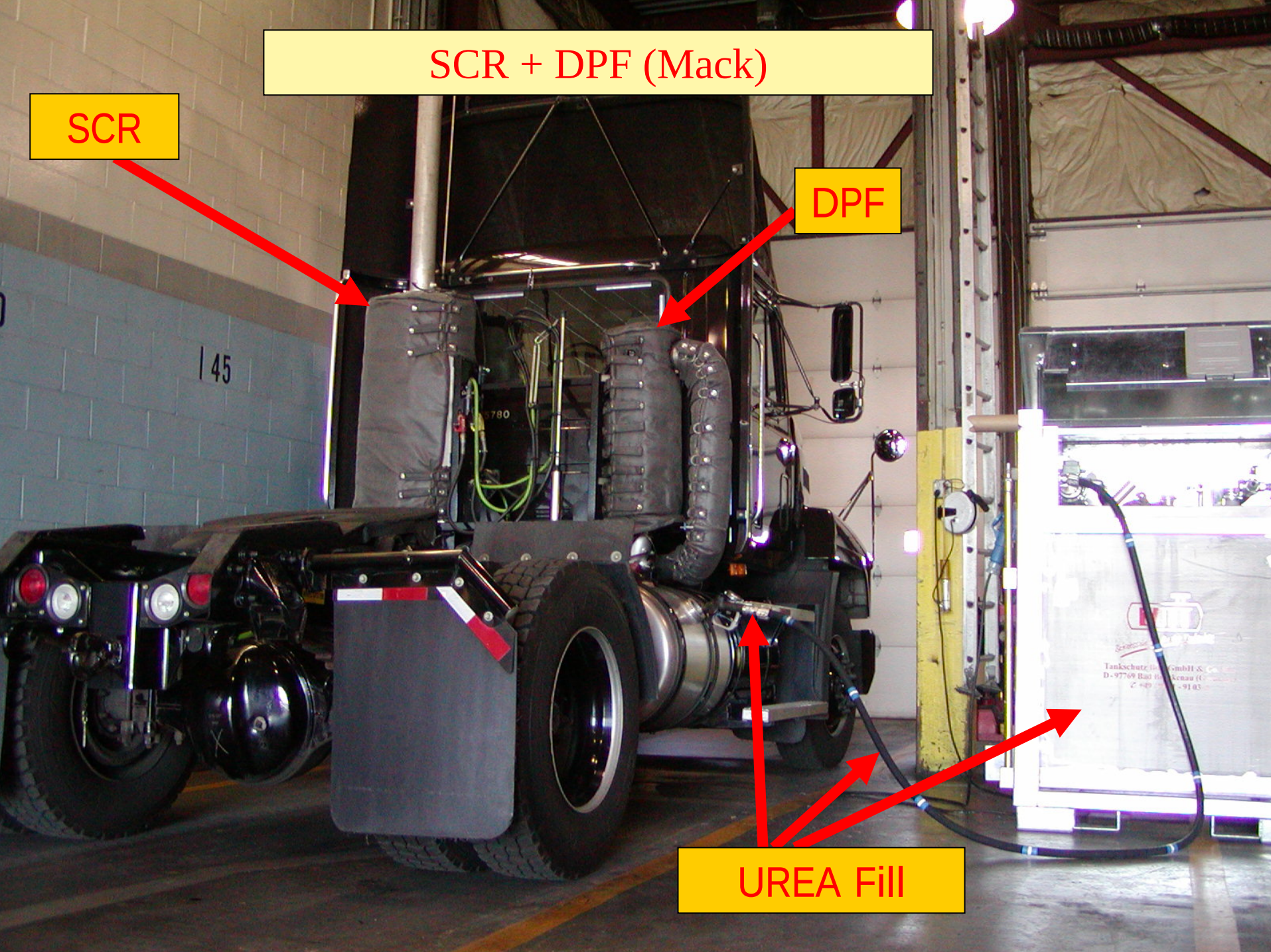


Figure 7. Open Loop Urea SCR System for Mobile Diesel Engines


SCR + DPF (Mack)
SCR
DPF
UREA Fill

Lean NOx Catalyst (LNC)

- What is it?
  - Systems injects diesel fuel into the exhaust stream and then catalyzes the reaction to reduce emissions.
- What does it do?
  - Reduces NOx (25-40%)
- Cost: $5,000 - $10,000 (when combined w/ DPF)
- Issues:
  - Can be paired w/ DPF for greater reductions
  - CARB verified for trucks
  - Fuel economy penalty of 3-7%

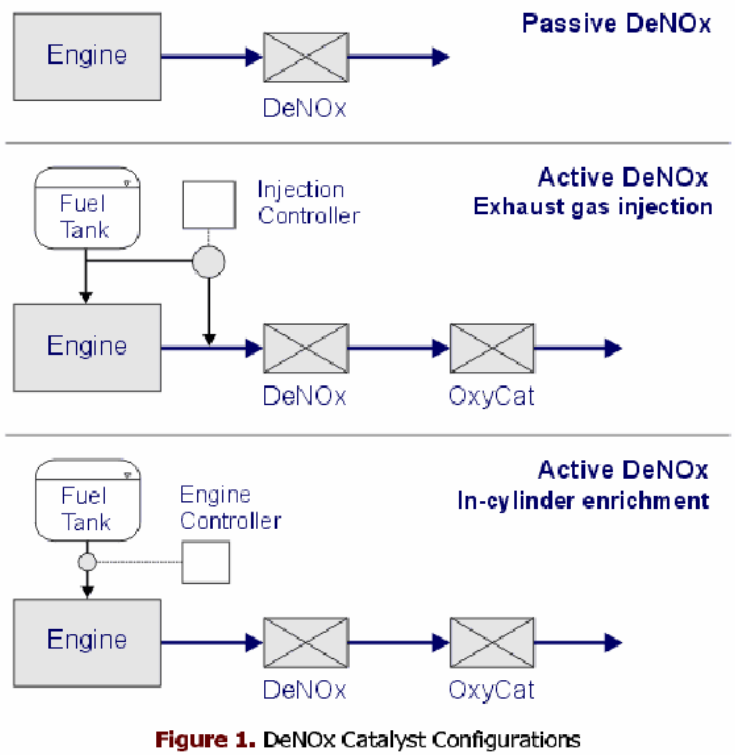
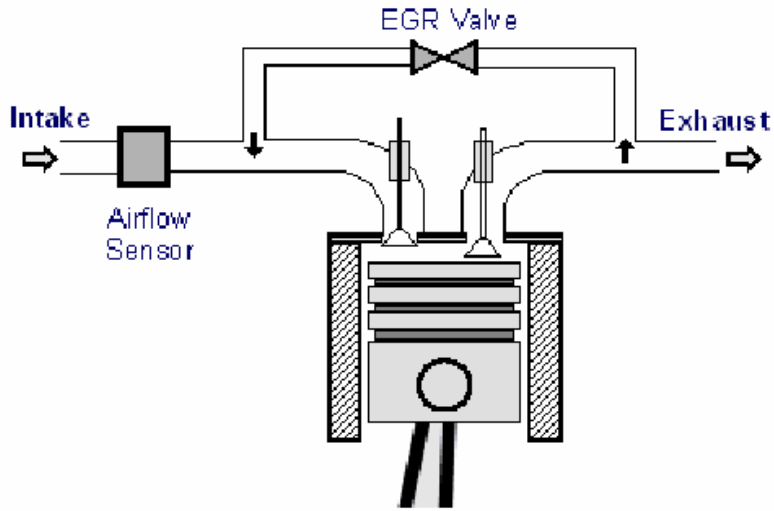


Figure 1. DeNOx Catalyst Configurations

$$[HC] + NO_x = N_2 + CO_2 + H_2O$$

Exhaust Gas Recirculation (EGR)

- What is it?
  - Device recirculates a portion of engine exhaust back into the engine to cool peak combustion temperatures and thus reduce NOx
- What does it do?
  - Reduces NOx (40-50%) if paired with a DPF
- Cost: $13,000 - $15,000
- Issues:
  - Can be paired w/ DPF for greater reductions
  - Fuel economy penalty of 1-4%



Repair/Rebuild

- Engines that are properly maintained and tuned perform better and typically emit less particulate matter and other pollutants.
- Rebuilding an engine can also significantly lower emissions in some cases and can be a cost effective option for high value equipment.
- Unless engines are properly maintained, other measures to reduce emissions may be futile.
- Properly maintained or recently rebuilt engines lower emissions by burning fuel more efficiently and can reduce operation costs through improved fuel economy and extended engine life.

Repower

- Repower refers to replacing an older engine with a newer, cleaner engine or replacing a diesel engine with one that can use alternative fuels.

- Where appropriate, a repower can also include substituting a cleaner highway engine for a nonroad engine.

Replace

- Replacing entire vehicles or machines may be the best option for equipment that is nearing the end of its useful life or was manufactured before stringent emissions standards were put in place.

  - Replacing older diesel equipment with newer diesel equipment
    - Such as uncontrolled engines: pre-1984 trucks or pre-1996 nonroad equipment

  - Replacing nonroad equipment with certified highway equipment built to stricter emission standards

  - Replacing diesel equipment with electric, hybrid or alternative fuel equipment (LNG, CNG, propane)
    - Hybrid switcher locomotive, electric cranes, LNG or PLG yard tractors, forklifts or loaders

Replace - cont'd

- Port of NY/NJ – acquiring the cleanest available technologies
  - Calculated air emissions from 2002 thru 2004.
  - Although number of pieces of equipment up 19%, operating hours up 5%, and the total number of containers up 25%,
  - fuel savings 20%
  - overall emission estimates tons per year have decreased

  NOx - 31% reduction
  VOC - 32% reduction
  CO - 32% reduction
  PM - 32% reduction (10 ppm)
  SO2 - 35% reduction

Operational Strategies

- Operational strategies reduce emissions by limiting the amount of time engines need to operate and creating systems to maximize efficient use of equipment.
- Truck Idle Reduction
  - Gate efficiencies
  - Web-based appointment systems or reservation system
  - Expanded hours or incentives for off-peak operation to avoid lines
- Substituting Electric Power for Diesel Power:
  - Electric Cranes
- Container management and reducing container movements through
  - Better IT management
  - Stacking practices
  - Direct intermodal transfers (i.e., cargo transferred directly from ship to rail)
- More efficient freight movement:

  Barging in lieu of trucking

  Substituting rail for trucking

Conclusions

- A wide variety of retrofit options are available for diesel engines to reduce HC, CO, PM and toxic emissions
- NOx retrofit controls are emerging
- A growing number of retrofit programs are being successfully implemented
- Technology development continues to expand the range of applications available for retrofit
- A successful retrofit program must be properly designed and implemented

Some Diesel Retrofit Web Sites

- U.S. EPA:
  - http://www.epa.gov/otaq/retrofit
  - http://www.epa.gov/midwestcleandiesel
- The Manufacturers of Emission Controls Association:
  - http://www.meca.org
  - Click on "Publications" to access MECA fact sheets and technical documents on diesel retrofit
- The Diesel Technology Forum:
  - http://www.dieseltechnologyforum.com/
- The California Air Resources Board's Diesel Risk Reduction Program:
  - http://www.arb.ca.gov/diesel/dieselrrp.htm

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